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PTPT REPORT NO. 76-21
AFPEA PROJECT NO. 75-P7-30

2

AD B019429

See 1473

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INTERIM REPORT
THE DEVELOPMENT OF BARRIER MATERIALS FOR FLEXIBLE AIRCRAFT ENGINE CONTAINERS

HQ AFALD/PTP
AIR FORCE PACKAGING EVALUATION AGENCY
Wright-Patterson AFB OH 45433

May 1977

NOTICE

ABSTRACT

The development of improved barrier materials for the construction of flexible aircraft engine containers in conjunction with a newly developed closure device (DSPS Report No. 76-17) has been completed. An extensive investigation was conducted on the properties of flexible plastic laminates and composites for barrier materials. Flexible containers fabricated from the selected barrier materials are stronger, tougher, and offer greater resistance to environmental elements than previous materials, providing over one year protection without redesiccation. They are easily installed and removed from the aircraft engine. Field tests are recommended before approval for production quantities.

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FOREWARD

The author acknowledges the valuable contributions of Robert J. Leugers, Emil Thomas, Edward Moravec and Randle Dukes of the Materials Engineering Division, Air Force Packaging Evaluation Agency; David Clouse, 4950TW/SUP; and Captain Ritmueller, P&W YFJF-F-15 SPO.

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INTRODUCTION

The purpose of this project is to develop improved barrier materials for the construction of flexible aircraft engine containers of advanced design and characteristics to provide a container with high strength, greater resistance to the environmental elements and lower water vapor transmission rate (WVTR) for a storage life of one year without redesiccation, at economical cost.

The replacement of metal containers (Figure 1) with flexible, reusable water vaporproof containers (MIL-C-9959, Type 3) (Figure 2) in the past ten years has made a major contribution to the utilization of cargo space, improved handling techniques, and satisfactory storage protection for aircraft engines. However, their deficiencies of poor oil resistance, high WVTR, susceptibility to puncture damage and difficulty of opening and closing the closure devices have prevented their full acceptance by using agencies. Figure 3 shows a flexible container installed on TF-39 engine for C-5 aircraft ready to be loaded on a C-141 aircraft.

Flexible containers developed under contract in 1969 (Figure 4) and tested early in 1970 did meet the requirements of MIL-C-9959, Type I (one year protection without redesiccation). However, the barrier material and closure device were too costly to be acceptable. Air Force Packaging Evaluation Agency has continued the development program to obtain a more cost effective container.

This report outlines the history, technical data and procedures in developing a cost effective MIL-C-9959, Type I flexible engine container. It identifies the development of a composite laminate barrier material which is now available from industry, and which exhibits properties and characteristics to meet the requirements of a flexible engine container. The development of a satisfactory closure device for easily opening and closing the container is documented in PTPT Report No. 76-37. Also, with the successful completion of the field tests, the barrier material and closure device should be considered for flexible containers to protect items such as missiles, ammunition and WRM items. Thus, the goal to use a less expensive outer container or overpack (not required to be water vaporproof) to serve for physical and dynamic protection with an effective flexible barrier container inside can be achieved. (This phase of the larger program will be covered in a subsequent report.) The flexible container identified in this report is now needed for protection of the more sophisticated aircraft engines such as the F-100 engine for the F-15 and F-16 aircraft (Figure 5

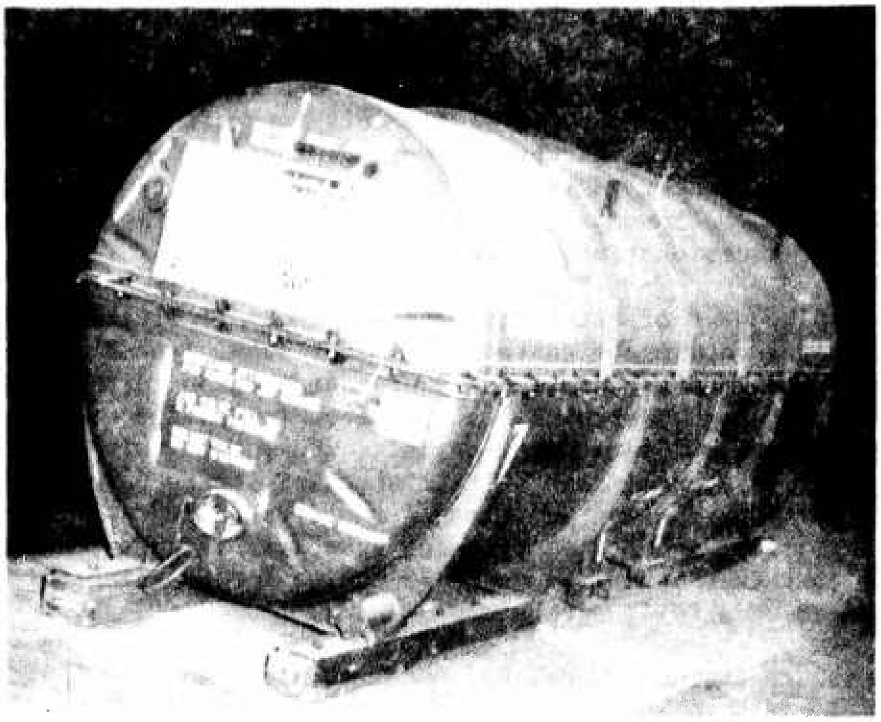


FIGURE 1. METAL CONTAINER FOR J-57 ENGINE FOR B-52 AIRCRAFT

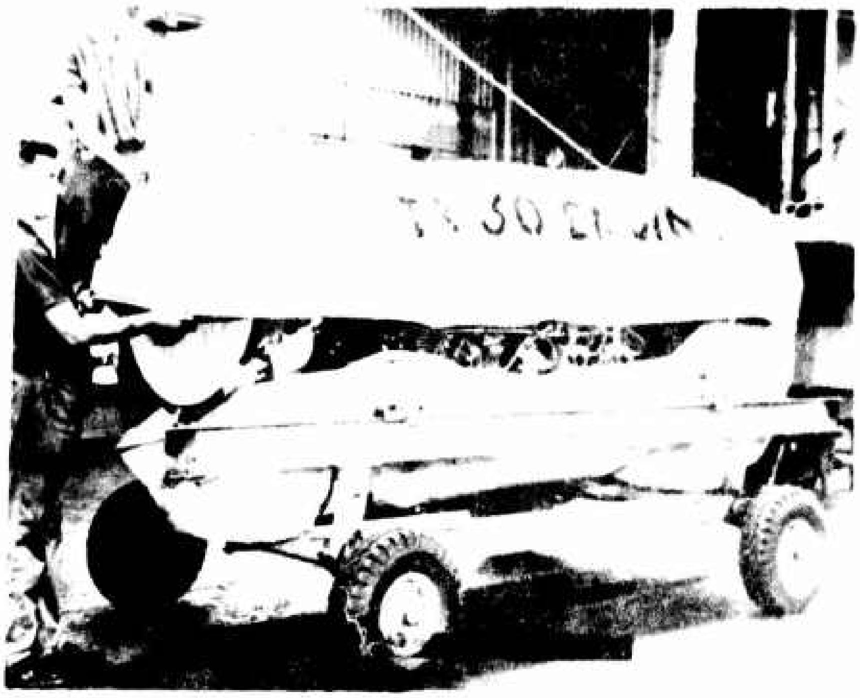


FIGURE 2. FLEXIBLE ENGINE CONTAINER FOR TF-30 ENGINE FOR THE F-111 AIRCRAFT

FIGURE 3. FLEXIBLE CONTAINER INSTALLED ON TF-39
ENGINE FOR C-5 AIRCRAFT

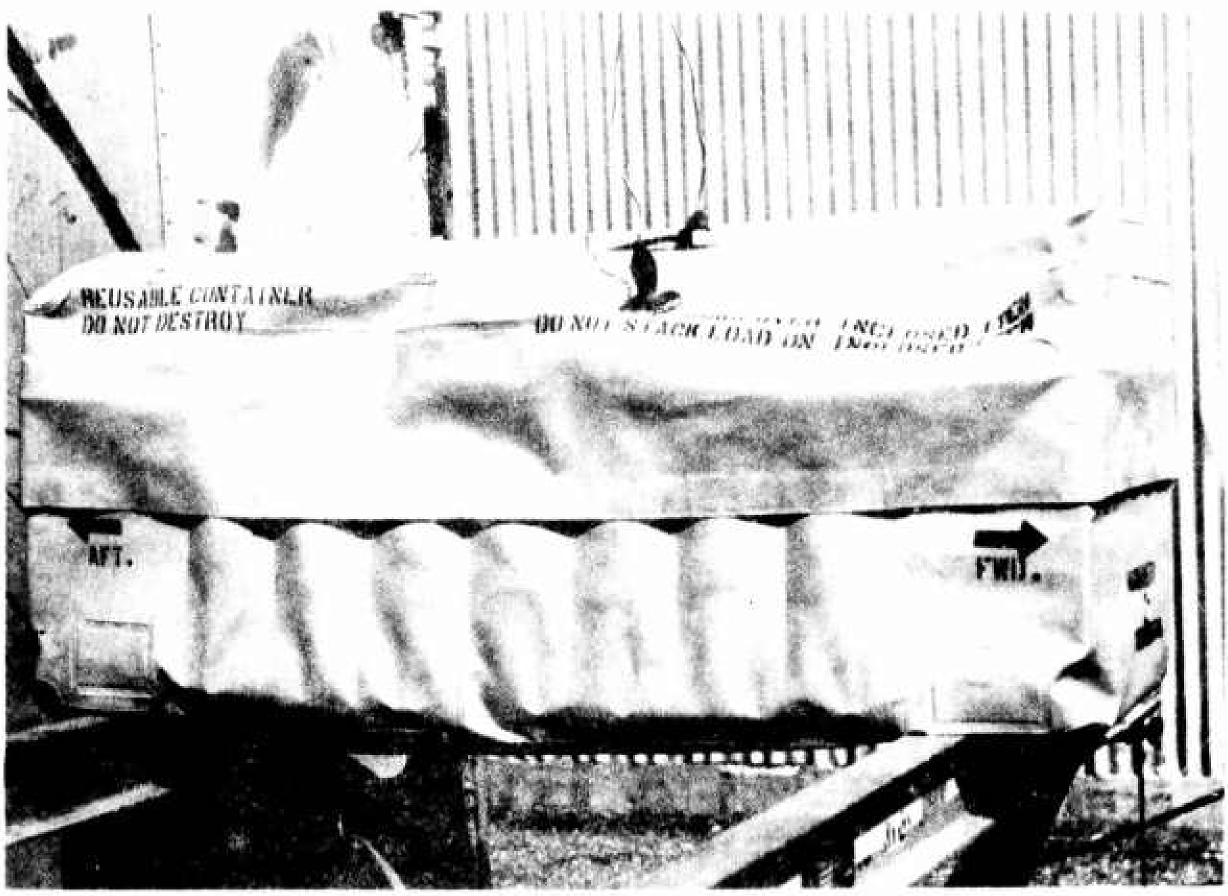


FIGURE 4. FLEXIBLE CONTAINER MANUFACTURED FROM DUPONT #264-3-1
BARRIER MATERIAL (ENVIRONMENTAL TEST AT EGLIN AFB, FL)

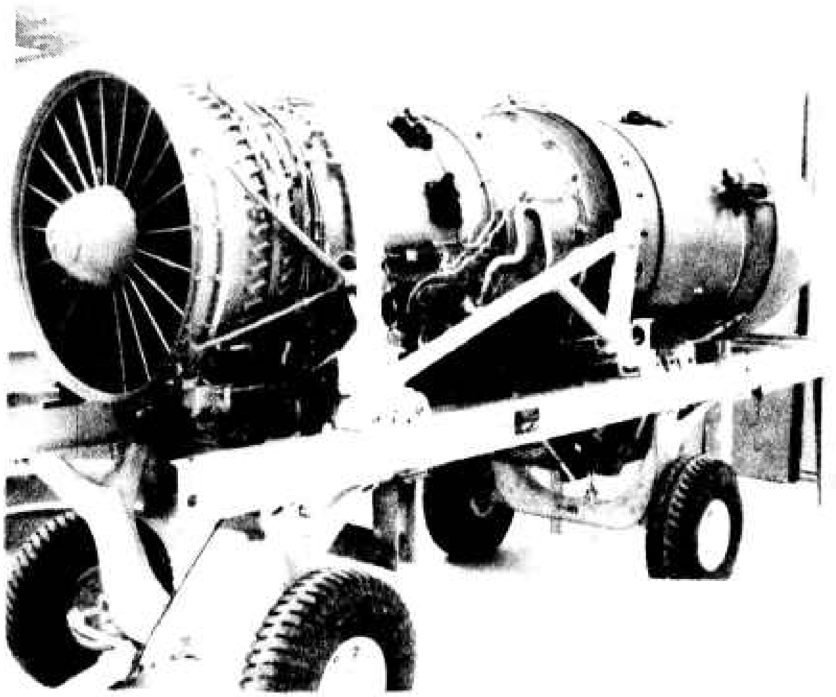


FIGURE 5. F-100 ENGINE FOR F-15 AIRCRAFT

and 6) that are now being placed in the distribution system. It is important that field tests be conducted on a timely basis.

DISCUSSION

The development program was divided into three phases:

Phase I - Survey and Analysis of Flexible Barrier Materials.
Phase II - Selection and Evaluation of Barrier Materials For Containers.
Phase III - Laboratory Evaluation of Prototype F-100 Containers.

PHASE 1 - SURVEY AND ANALYSIS OF FLEXIBLE BARRIER MATERIALS

The Air Force Packaging Evaluation Agency has been conducting several development and testing programs relating to flexible barrier materials. This has provided a large amount of information and engineering data for use in this project to develop flexible containers. Tables I, II and III provide a summary of characteristics of typical polymers, plastic films, and composites taken from the final report of All American Engineering (AAE) Corporation Report No. AF275-A, Design and Development of Aircraft Engine Flexible Containers. Tables IV and V are taken from AFPEA/PTPS Report No. 73-1, Water Vapor Transmission Rates (WVTR) of Flexible Barrier Materials.

From these studies several materials were identified that have excellent water vapor barrier properties which make them candidates, in combination with other plastic films, for laminates that will meet or exceed the requirements of MIL-C-9959, Grade A, barrier materials. These barrier materials are identified as Saran, aluminum foil and Aclar. It is apparent from their physical properties that these materials alone would not make satisfactory materials for flexible containers, because of deficiencies such as poor heat seal-ability, low puncture resistance, etc.

The contractual barrier development program with All American Engineering Corporation (AAE Report No. 475) identified a superior barrier material; namely, DuPont No. 264-3-1. This material is a composite of Polyurethane/Saran/Nylon Cloth/Polyurethane/Saran; the thickness of the material is 0.35 to 0.40 inches. Outdoor exposure tests at Eglin AFB, Florida with containers fabricated of the DuPont 264-3-1 with a Talon Type O.E.B., Size 86 metal-tooth zipper closure (Figure 3) and desiccated according to the requirements of MIL-C-9959 gave over one year protection. (The environment inside the container

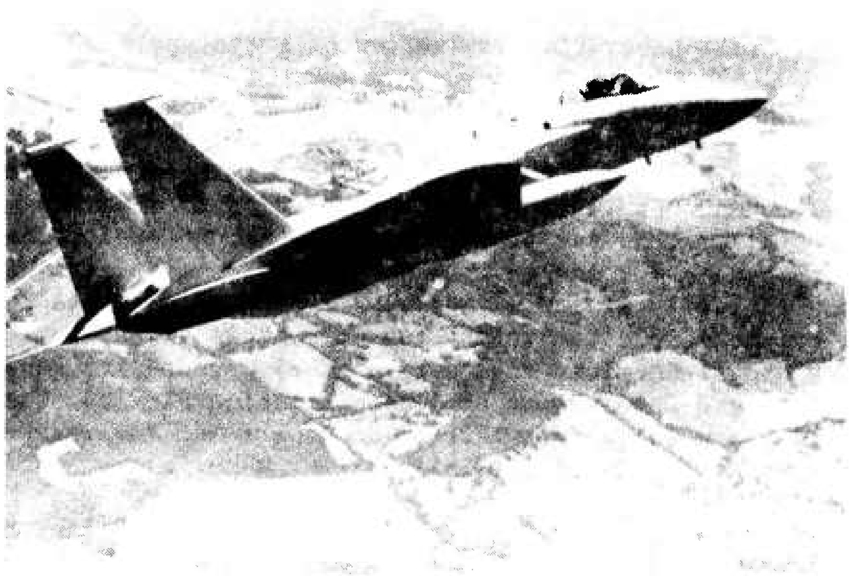


FIGURE 6. F-15 AIRCRAFT

TABLE I

TYPICAL POLYMER PROPERTIES

Properties	Natural Rubber	Butyl	Buna N	Silicone	Neoprene	VITON Fluoro-elastomer	HYPALON Synthetic Rubber	Urethane Rubber
Tensile strength(psi)	over 3000	over 1500	below 1000	below 1500	over 3000	over 2000	over 2500	over 4000
Specific gravity (base material)	0.93	0.92	1.00	-	1.23	1.85	1.12-1.28	1.05
Adhesion to fabrics	excellent	good	good		excellent	good to excellent	good	excellent
Tear resistance	good	good	fair	poor	good	fair	fair	excellent
Abrasive resistance	excellent	good	good	poor	excellent	good	excellent	outstanding
Permeability to gases	fair	very low	fair	fair	low	very low	low to very low	fair
Swelling in lubricating oil	poor	poor	very good	fair	good	excellent	good to excellent	excellent
Resistance To:								
Oil and gasoline	poor	poor	excellent	fair	good	excellent	good	excellent
Water absorption	very good	very good	fair to good	good	good	very good	very good	good at room temp., poor at 212°F.
Ozone	fair	excellent	fair	excellent	excellent	outstanding	outstanding	outstanding
Sunlight aging	poor	very good	poor	excellent	very good	very good	outstanding	good
Heat aging	good	excellent	excellent	outstanding	excellent	outstanding	excellent	good
Flame	poor	poor	poor	fair	good	good	good	fair
Heat	good	excellent	excellent	excellent	excellent	excellent	excellent	good
Cold	excellent	good	good	excellent	good	good	good	excellent
Relative cost to PVC	lower	lower	lower	five times	lower	at least 10 times	twice	slightly high

Acknowledgement is made to the duPont Company for compilation of material characteristics.

TABLE II

CHARACTERISTICS OF PLASTIC FILMS FOR BARRIER MATERIALS EVALUATION PROGRAM

Materials	Source	WVTR $100^{\circ}F$ 90 95% RH G/100 Sq. In. /24 Hrs	Oil Resistance to MIL-L-7808	Flexibility at Low Temperatures	Heat Sealing
Aclar .004"	Allied Chem.	.15	Satisfactory	Satisfactory	Satisfactory
Mylar .005"	DuPont	.36	"	"	Poor
Nylon	DuPont	6.80	"	"	"
Polyethelene .006"		.21	"	Unsatisfactory	Satisfactory
.003"		.30	"	"	
Polypropylene .005%	Hercules	.15	"	Satisfactory	
Polyurethane .010"	B.F. Goodrich	2.00	"	"	Satisfactory
.020"		.35	"	"	"
Polyvinylchloric .010"	B.F. Goodrich	.35	Unsatisfactory	"	"
Saran .002"	Dow Chem.	.06-.08	Satisfactory	"	"
Tedlar PVR .001"	DuPont	3.24	"	"	Poor
Teflon FED .001"	DuPont	.16	"	"	Satisfactory

TABLE III

BARRIER MATERIAL TEST DATA

Revised 4-3-70 Sheet 1 of 3

Manufacturer Designation	Material	Heat Sealable	MIL-L-7808 Resistance (Prelim)	WVTR: Prelim. Unexposed and Unflexed	WVTR: After Room Temp Flex: Before Expos.	WVTR: After Room Temp Flex: After Expos.	WVTR: After Low Temp Flex	Comments	Other Test Data	Color	Weight oz/yd^2	Cost $/yd^2
Specification		Preferred	160° F 72 Hrs.	A. None B. None	0.02 0.05	0.03 0.07	0.20 0.25			Blue No. 15045	49.6	
Allison/Morgan	PVC/NY/PVC	Yes	Unsat.	> 0.1				Discard due to Unsat Oil Res.		Green Blue		
NAVAN	PVC/NY/PVC	Yes	Unsat.	> 0.1				"		Light Blue		
GE/NAVAN	PVC/NY/PVC	Yes	Unsat.	> 0.1				"		Dark Blue		
Chemical Rubber												
No. 2598	NEO/NY/NEO	No	Sat.	< 0.05	See Chart		A		Tear Strength Low (18 VS 45)	Orange	22 ± 1.5	
No. 21482	PVC	Yes	Sat. (?)	Unsat.				Discard due to High WVTR	Tear Strength Low (13 VS 45)	Yellow	9.0	
Dow												
No. P2-433109	EVA Film	Yes	Unsat.	< 0.05				Suitable for Laminate (?)		Clear		
DuPont												
No. 72-020	HYP/NY/HYP	No	Sat.	> 0.1						White		
No. 236-139-1	HYP/NY/Saran/NY	Yes	Unsat.					Discard due to Unsat Fluid Resistance		White	17.9	
No. 236-150-1	"	Yes	Unsat.					"		White	28.8	7.15
No. 236-151-2	"	Yes	Unsat.					"		White	20.8	7.15
No. 236-162-2	VI/NY/Saran/VI	Yes	Unsat.					"		Blue		
No. 236-162-3	"	Yes	Unsat.					"		Blue		
No. 88-010	BUTYL	No	Unsat.	< 0.05 See Cht.				"				
No. 236-109-1	HYP/NY/HYP	Yes	Unsat.	See Cht.				"		White		
No. 236-175-2	P'ane/NY/SA	Yes	Sat.	< .01	< .01			Suitable "A"		Blue	28	7.70
No. 236-175-3	SA/P'ane NY/SA	Yes	Sat.	< .01	< .01			Suitable "A"		Blue	27	8.00
No. 236-175-4	SA/P'ane/NY/SA/P'ane	Yes	Sat	< .01	< .01	< .01	.12	Suitable "A"	Blocking & Flame Resist. to be Imp.	Blue	33	10.00
No. 236-181-3	P'ane/NY/SA (.002)	Yes	Sat.	< .01				Suitable "A"		Blue	22	
No. 236-181-2	P'ane/NY/SA (.002)	Yes	Unsat.	> .2	> .2					Blue	20	
No. 236-195-2	SA/P'ane/NY/P'ane	Yes						This sample is an improved #236-175-4 never tested. Superceded by #264-3-1		Blue	33	10.00
No. 264-3-1	SA/P'ane/NY/SA/P'ane	Sat.	Sat.	—	< .01	~ .02	< .01		Prel. Oil. Tests MIL-J-5624 Sat. MIL-O-6081 Sat. MIL-C-6529 Sat.	Blue	33	10.00
Joanna-Western												
No. 1	P'ane/NY/P'ane	Yes	Sat.	> 0.1	Unsat.		Unsat.	Suitable for Laminate(?)	At U.S. Testing Lab	Black		
No. 2	P'ane P'ane Film	Yes	Sat							Black		
John Royle (A. Brown) No. 1292-252	PVC/NY/PVC	Yes	Unsat.							Blue		
Ludlow (Marvellum) Marvelgard No. 52	AL/Tyvek/P'ene/Ny Comp.	No	Sat.				Unsat.	Delaminates Badly after Flexing		Silver		
Reeves												
No. 25411	PVC/NY/PVC	Yes	Sat.	> 0.2	Unsat. See Cht.		B	Imp. interim material for Tinker	At U.S. Testing Lab	Blue	18.4	1.76
No. SW-895	Tedlar/NY/NEO	No	Sat.	> 0.2				Lab sample only. Superceded by No. 15423		Grey		
No. 15423	"	No	Sat.	> 0.2				Suitable for Laminate		White/Black		
Morgan Film	?	N/K	No	< 0.01 See Cht.				V. small sample. Suitable for laminate.		White	V Low	

TABLE III (Cont'd.)

BARRIER MATERIAL TEST DATA

Manufacturer Designation	Material	Heat Sealable	MIL-L-7808 Resistance (Prelim)	WVTR: Prelim. Unexpos and Unflexed	WVTR: After Room Temp Flex, Before Expos.	WVTR: After Room Temp Flex, After Expos.	WVTR: After Low Temp Flex	Comments	Other Test Data	Color	Weight oz/yd²	Cost $/yd²
Specification		Preferred	160°F 72 Hrs.	A. None B. None	0.02 0.05	0.03 0.07	0.20 0.25			Blue No. 15045	49.6	
AFLC Pkg. Lab No. 1	.010 J.W. P'lane .001 Alum. Foil .010 J.W. P'lane		Sat	?				Small Lab Sample		Black		
No. 2	.010 BFG P'lane .001 Alum. Foil .010 BFG P'lane		Sat					Small Lab Sample				
No. 3	.010 BFG P'lane .001 Alum. Foil Ripstop Nylon .010 BFG P'lane		Sat.		B A			More samples req'd.				
No. 4	.010 J.W. P'lane .001 Metalized Polyester Ripstop Nylon .010 J.W. P'lane		Sat	A	< .05			Small Lab Sample		Black		
No. 5	.010 P'lane MIL-B-131 .010 P'lane		Sat	A	> .05							
AAE #1	Reeves 26411 .002 Hi-Den. Polyethylene	Yes	Sat		> .2			Unsat.	Lamination using Thiokol 390 ADH			
AAE #2	Chem Rubber #2598/ P'lane	Yes	Sat		.2			Unsat.	"			
AAE #3	Reeves 15423 Chromal 370035	Yes	Sat.	< .01	< .01			Suitable "A"	"			
AAE #4	Reeves 15423 J.W. P'lane .005"	Yes	Sat.	> .2				Unsat.	"			
AAE #5	J.W. P'lane NY/3M Scotch Pack Type 20	No R.F. Heat	Sat	< .01	< .01			Suitable "A"	"			
AAE #6	Chem Rubber 21482/ 3M Scotch Pack .005 P'lane	No R.F. Heat	Sat		Unsat			Chem Rub. mat'l very difficult to laminate above 200°F	"			
AAE #7	Chem Rubber 21482/ .010 EEA Dow/.005 P'lane	Yes	Sat		Unsat			"				

TABLE III (Cont'd.)

BARRIER MATERIAL TEST DATA

Sheet 3 of 3

Manufacturer Designation	Material	Heat Sealable	MIL-L-7808 Resistance (Prelim)	WTVR Prelim. Unexpos and Unflexed	WTVR After Room Temp Flex Before Expos.	WTVR After Room Temp Flex After Expos.	WTVR After Low Temp Flex	Comments	Other Test Data	Color	Weight oz/yd²	Cost $/yd²
Specification		Preferred	160°F 72 Hrs.	A. None B. None	0.02 0.05	0.03 0.07	0.20 0.25			Blue No. 15045	49.6	
AAE #8 & 9	Reeves 915423/ 3MScotch Pack/.005 P'ane	Yes	Sat	Sat	< .01			Suitable "A"	Lamination using Thiokol 390 ADH			
AAE #10	.010" P'ane/ NY/6 Mil P'ene/ .010 P'ane	Yes	Sat	Sat	B			Suitable "B" (Dow PZ-4333.27)film	"			
AAE #11	.010 Poly NY/3M Scotch Pack/.010 Poly	Yes	Sat	< .01				Gelbo Flex under power for flexing *	"			
AAE #12	SA/J.W. P'ane MY/SA	Yes	Sat	.01		A						

NOTE:
NY = Nylon; VI = Vinyl; P'ane = Polyurethane; P'ene = Polyethylene
NEO - Neoprene; HYP = Hypalon; EVA - Ethylene Vinyl Acetate; SA = Saran

TABLE IV

WVTR Test Data -- Opaque Barrier Materials

NOTE: The barrier materials included below were tested for possible use in flexible engine containers.

TRADE NAME	COMPOSITION	WATER VAPOR TRANSMISSION RATE: TEST CONDITIONS	gms per 100 sq in per 24 hrs	METHOD	REMARKS
Marvelguard 52	Aluminum/Tyvek/Polyethylene/Nylon	As Rec'd, no flex.	0.04	H	Delaminated badly on flexing.
		As Rec'd, 100 flexes.	0.05	H	
		As Rec'd, 500 flexes.	0.26	H	
		As Rec'd, 1800 flexes.	0.85	H	
Marvelguard 42	Tyvek/Aluminum/Surlyn	As Rec'd, no flex.	0.005	H	
		As Rec'd, 500 flexes.	0.05	H	
		As Rec'd, 1000 flexes.	0.1	H	
		As Rec'd, 1800 flexes.	0.12	H	
DuPont 264-3-1	Saran/Polyurethane/Nylon/Saran/Polyurethane	As Rec'd, no flex.	0.07	H	$10.00/sq yd
NAVAN	PVC/Nylon/PVC	As Rec'd, no flex.	0.40	H	
-	1.5 mil stainless steel 304/15 mil Surlyn	As Rec'd, no flex.	0.006	H	
Scotchpak (3M)	Polyester metalized film (No.20), 2.5 mils	As Rec'd, no flex.	0.001	H	
		As Rec'd, 18 flexes.	0.26	H	
	10 mil polyurethane/1 mil nylon cloth/1 mil Teflon FEP	As Rec'd, no flex.	0.10	H	

(Continued)

TABLE IV

(Continued)

TRADE NAME	COMPOSITION	WATER VAPOR TRANSMISSION RATE TEST CONDITIONS	gms per 100 sq in per 24 hrs	METHOD	REMARKS
-	1 mil Teflon FEP/10 mil nylon cloth/1 mil Teflon FEP	As Rec'd, no flex.	0.023	H	
Marvelguard 52A	Surlyn/Aluminum/Nylon cloth/ Tyvek	As Rec'd, flexed MD.	0.0099	-	Test data from All-American Engineering Co.
		As Rec'd, flexed CD.	0.0184	-	
		Low temp. MD flex.	0.0082	-	
		Low Temp. CD flex.	0.0260	-	

TABLE V

WVTR Test Data -- Transparent Films and Laminates

COMPOSITION	MANUFACTURER OR TRADE NAME	THICKNESS MILS	WATER VAPOR TRANS RATE gms per 100 sq in per 24 hrs	METHOD	REMARKS
Polyethylene		2.0	0.4	H	Clear
Polyurethane		5.0	0.3	H	Clear
		15.0	0.07	H	Clear
High density cross laminated polyethylene	Appleton Coated Paper Co.	4.0	0.15	H	White Opaque
Polypropylene	Hercules	10.0	0.12	H	Clear
	Tuftane TF330	3.0	9.0	H	Yellow-clear
	Tuftane TF310	30.0	0.91	H	Blue
Fluorohalocarbon	Aclar (Allied Chem)	1.0	0.16	H	Clear-Lowest WVTR of all transparent films. Expensive.
Ionomer	Surlyn (DuPont)	6.0	0.41	H	Good for skin packaging.
		13.0	0.08	H	
Teflon FEP	Teflon (DuPont)	1.0	0.72	H	
PVDC (Saran) Laminate	Dow Saranex PZ 1620.33.	1.5	0.18	H	
	PZ2005.07	4.5	0.09	H	
	PZ2005.22	2.0	0.11	H	
	PZ2000.29	2.0	0.17	H	
PVDC-coated nylon (1 mil Capran 77K)/Surlyn 1601 (5 mil)	MIL-F-45215 (SM) Perma Pak-Allied Chem.	6.0	0.24	H	Design for skin packaging.
Aclar 22A (1.5 mil)/Surlyn (5 mil)	Allied Chemical	6.5	0.019	H	Watervaporproof skin packaging. $2.30 per sq yd.
Aclar/Polyester (MIL-F-22191A, Type I)	Film-O-Rap 7750 Champion Packages	5.0	0.018	H	
Polyethylene (2 mil)/Polyester (0.5)/ Aclar (0.75)/Nylon 6(2)	Film-O-Rap 7770	5.25	0.016	H	
Polyethylene/Nylon/Polyethylene	Milprint	5.0	0.174	H	Used in DuPont oil pouches.
Polyethylene/Saran/Polyethylene	Dow Saranex PZ 2000.36	4.0 (1 ply)	0.079	H	
		8.0 (2 ply)	0.037	H	
		12.0 (3 ply)	0.024	H	

did not reach above 40% RH at 73°F.) The same container desiccated according to the requirements of MIL-C-9959 exposed to an environment of 80% RH at 80°F in a humidity cabinet gave over one year protection. The high cost of this barrier material of approximately $16-18 per square yard, and the high cost of the Talon zipper closure of approximately $8-10 per linear foot prohibited its adoption for production use. However, this container (DuPont 264-3-1 barrier material) has been adopted as a base line for selection of design, barrier materials, and closure devices.

A search for a more economical barrier material and closure device was conducted. The Global Chemical Systems Corporation, Gardena, CA, approached the Air Force regarding polyurethane covers for aircraft jet engines and helicopters. At about the same time, the Army Aviation Systems Command (AMSAV-QMP) consulted AFPEA on flexible containers for helicopters using polyurethane (not polyurethane/saran), and the possibilities of using MIL-C-9959. Based on AFPEA's studies, advice was presented that polyurethane alone would not have the barrier properties necessary for long-term storage. Subsequently, the Global Chemical Systems Corporation submitted a composite laminate of Polyurethane/Saran/Polyurethane (approximately 0.020") which they developed under AFPEA's guidance.

Throughout this time period of several months, several industries submitted selected plastic laminates for evaluation for flexible engine containers. These materials were evaluated for WVTR; the results are presented in Table VI. The Global No. 4051 laminate has very low WVTR and other desirable properties as listed in Tables VII, VIII, and IX. However, several other materials also had sufficient barrier properties, along with other desirable characteristics, and were therefore included in Phase II, Selection and Evaluation of Barrier Materials for Containers.

PHASE II - SELECTION AND EVALUATION OF BARRIER MATERIALS FOR CONTAINERS

The barrier materials in Table VII were selected from Phase I for container evaluations during Phase II. MIL-B-131 and DuPont No. 264-3-1 were included in Phase II for base line criteria and not necessarily considered as barrier materials for aircraft engine flexible containers.

The WVTR evaluation of the barrier materials as containers was conducted according to a modified Federal Test Method Standard No. 101B, Method 3030. The modified test method procedure is described

TABLE VI

WATER VAPOR TRANSMISSION RATES
ON SELECTED BARRIER LAMINATED MATERIALS

BARRIER MATERIAL	GRAMS PER 100 SQ. INCHES PER 24 HOURS* NO GELBO FLEXING		20 GELBO FLEXES		100 GELBO FLEXES		500 GELBO FLEXES		1000 GELBO FLEXES		2000 GELBO FLEXES	
	NOT AGED	AGED**	NOT AGED	AGED**	NOT AGED	AGED**	NOT AGED	AGED**	NOT AGED	AGED**	NOT AGED	AGED**
DuPont #264-3-1 DuPont Company Wilmington, Del	.070	.107		.063	.040						.035	
Enviropak #1225 (MIL-C-9959, Type II) Enviropak, Inc. Elsegundo, CA	.400	.362	.373	.382	.456	.411	.439		.388			
Enviropak - 1500P5 Enviropak, Inc. Elsegundo, CA	.400											
Reeves - Cover Light #18073 Reeves Brothers Company New York, NY	.030	.039		.079		.083						
American Can Tooth Paste Tube Stock American Can Company Cleveland, OH	.010	.003	.016	.005	.905		2.178		1.065			
Griffolyn #85 B/W Griffolyn Co. Inc. Houston, TX	.040	.108	.071	.082	.070	.087	.078		.071		.080	
Goodrich - Chlorinated Polyethylene B.F. Goodrich Chemical Co. Cleveland, OH	.090	.205	.164	.234	1.026	.266	.983		1.055			
Marvel Gard 72 Ludlow Corp. Holyhoke, MA	.007	.021	.026	.300	.022	.235	.093		.290		.691	
MIL-B-131 (Nylon Backing)	.004	.003	.005	.007	.005	.012	.024		.060		.086	
Global #4051 Global Chemical Systems, Inc. Gardena, CA	.071	.054	.065	.061	.064	.034	.072		.064		.067	

* WVTR Conducted on Honeywell Tester - 100°F at 95% R.H.
** Aged and Gelbo Flexed According to MIL-C-9959

TABLE VII

COMPOSITION OF SELECTED BARRIER MATERIALS

MATERIALS	COMPOSITE CONSTRUCTION	COST/SQ. YD. (ESTIMATED)
Du Pont - #264-3-1	Polyurethane/Saran/Nylon Cloth/Polyurethane/Saran	$15
Enviropak #1227	Polyvinyl Chloride/Nylon Cloth/Sara	$4-5
Reeves - Cover Light #18073	Polybutylene/Glass Mat/Polypropylene Foam	$4-6
American Can Company Toothpaste Tube Stock	Polyethylene/Heavy Aluminum Foil	$2-3
Goodyear Company Chlorinated Polyethylene	Chlorinated Polyethylene	$2-3
Marvellum Company Marvel Gard #72	Polyethylene/Nylon Cloth/Aluminum Foil/Surlyn	$0.75-1.50
MIL-B-131 Nylon Gacking	Polyethylene/Aluminum Foil/Nylon	$0.60
Global Chemical Systems Corp #4057	Polyurethane/Saran/Polyurethane	$4-5
Griffolyn #85 B/W	High Density Polyethylene/Nylon Scrim/High Density Polyethylene	$2

TABLE VIII

WATER VAPOR TRANSMISSION RATES
ON BARRIER MATERIALS
AS ONE CUBIC FOOT FLEXIBLE CONTAINERS (NOT DESICCATED)

BARRIER MATERIALS AS CONTAINERS	GRAMS PER 100 SQ. INCHES PER 24 HRS AT		
	95% RH - 100°F	80% RH - 80°F	50% RH - 73°F
DuPont 264-3-1 without closure	0.050	0.039	0.003
Enviropak #1227 without closure	0.104	0.035	0.009
Reeves - Cover Light #18073 without closure	0.100	0.024	0.009
American Can Toothpaste Tube Stock without closure	0.050	0.053	0.009
Griffolyn #85 B/W without closure	0.050	0.018	0.002
Goodrich - Chlorinated Polyethylene without closure	0.100	0.022	0.010
Marvel Gard #72 without closure	0.080	0.015	0.005
MIL-B-131 (Nylon Backing) without closure	0.020	0.009	0.006
Global #4051 without closure	0.028	0.009	0.003
Global #4051* with closure	0.060	-----	-----

*The WVTR tests at 80%RH/80°F and 50%RH/73°F have not been conducted

TABLE IX

COMPARISON OF THE WVTR OF DUPONT 264-3-1
AND GLOBAL #4051 BARRIER MATERIALS
SHEET MATERIAL AND CONTAINERS
GRAMS PER 100 SQ. INCHES PER 24 HRS

BARRIER MATERIAL	AS RECEIVED**		AGED**		AS ONE CUBIC FOOT CONTAINER		
	NO FLEX	2000 FLEXES	NO FLEX	100 FLEXES	100°F 95% RH	80°F 80% RH	73°F 50% RH
DuPont #264-3-1*							
As Sheet Material	0.07	0.035	0.106	0.039	---	---	---
As Cubic Foot Container Without Closure	---	---	---	---	0.05	0.039	0.003
Global #4051							
As Sheet Material	0.07	0.067	0.054	0.034	---	---	---
As Cubic Foot Container Without Closure	---	---	---	---	0.03	0.009	0.003
With Closure 24" Length	---	---	---	---	0.06	---	---

* DuPont #264-3-1 - 2' x 2' x 5' container with Talon closure gave over one year protection outdoors at Eglin AFB, FL (A.A.E. Report AF 275-A).

** Conducted according to Para 4.5.2.6, MIL-P-9959, Container; Shipping and Storage.

in the Appendix. This method of testing barrier materials as one cubic foot containers (Figure 7) is being used as a tentative method for obtaining more meaningful data in evaluating barrier materials (including closure) for long-term protection.

Two types of tests were conducted using one cubic foot containers: (1) WVTR without the use of desiccant and (2) specific protection period per MIL-C-9959 (Para 3.4.2) using desiccant.

Table VIII is a summary of the WVTR of the selected barrier materials as one cubic foot containers. The Global one cubic foot container without a closure had one of the lower WVTR at the various humidity/temperature levels. Table IX shows a comparison of the WVTR properties of DuPont No. 264-3-1 one cubic foot container and Global No. 4051 one cubic foot container. The values for the sheet material are approximately equivalent. Comparing the one cubic foot containers without closures the Global No. 4051 container has a slightly lower WVTR than the DuPont container. The Global container with the 24" length extruded polyurethane closure is approximately equivalent in WVTR to the DuPont No. 264-3-1 container without a closure. Since a 2' x 2' x 5' container (Figure 7) made of DuPont No. 264-3-1 barrier material and a Talon metal tooth closure exceeded the one year protection period specified in MIL-C-9959 (Type I container) during outdoor storage at Eglin AFB, Florida (AAE Report AF275-A) without redesiccation, it can be assumed that a flexible container constructed of Global No. 4051 barrier material, and the extruded polyurethane closure should exhibit the same one year protection under similar conditions.

The data in Table X further indicates that a flexible container manufactured from Global barrier material number 4051 and the extruded polyurethane closure device will meet the specified protection period of one year without redesiccation as required by MIL-C-9959, Type I container. This table shows the results of a simulated test of one cubic foot containers using 10% of the desiccant required for a one year protection period. At the end of 37 days, the relative humidity in the container had reached a level of 31%. By extrapolation it is estimated that the time required to reach 40% RH would be 60 days. Based on these results with 10% of the desiccant specified, it can be further estimated that with 100% of the desiccant required by MIL-C-9959, the container will provide over 1-1/2 years of protection.

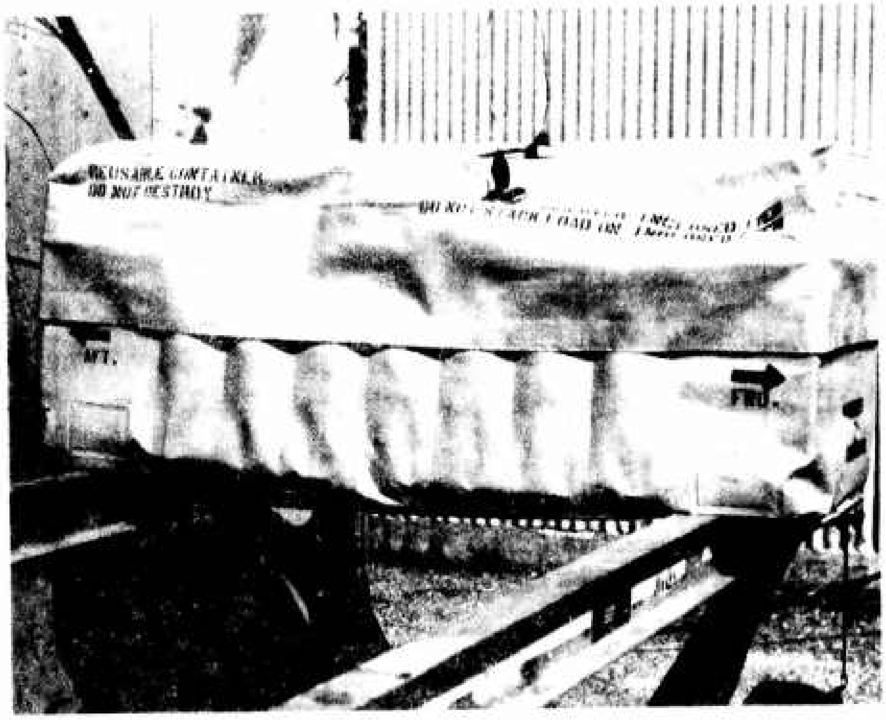


FIGURE 7. EXPERIMENTAL PROTOTYPE CONTAINER UNDER TEST AT EGLIN AFB, FL (DuPont Barrier Material 264-3-1 and Talon Metal Tooth Closure)

TABLE X

SPECIFIC PROTECTION PERIOD EVALUATION
MIL-C-9959, TYPE I CONTAINER
ENVIRONMENT - 80% RH AT 80°F

CONTAINER	UNITS OF DESC. FOR ONE YEAR FOR ONE CUBIC FOOT CONTAINER MIL-C-9959, TYPE I	UNITS OF DESC. FOR 10% OF ONE YEAR (37 DAYS)	DAYS TO REACH 40% RH (FROM 5% RH)	ESTIMATED PRO-JECTED DAYS TO REACH 40% RH (FROM 5% RH)	ESTIMATED SPECIFIC PROTECTION PERIOD USING 100% DESC, MIL-C-9959, TYPE I CONTAINER
Global Barrier Material #4051 Closure-Extruded Stand-Up - Polyurethane	26.4	2.64	>37 (the container reached 31% RH in 37 days)	60	1-1/2 years
Global Barrier Material #4051 No Closure (Heat Sealed)	26.4	2.64	>37 (the container reached 15% RH in 37 days)	100	2-1/2 years

The Global Chemical Systems Corporation furnished AFPEA a container for the TF34-100 engine (Figure 8). This container was used to check out the ease of opening and closing the closure device and the flexibility of the container at lower temperatures. The closure devices were easily opened and closed at room temperature. The container was placed in a cold chamber at 32°F. After 24 hours, the container closure device was opened and closed with moderate effort. At 0°F, the closure device became more rigid, and difficult to open and close. At -32°F, the closure was not operable; however, the closure or the container did not fracture upon bending. These results were considered acceptable.

The container was then inflated with air to a taut condition. It remained in a taut condition for over three months at room temperature showing no leakage over this period of time.

Table XI is a summary of the physical properties of the Global No. 4051 barrier material. The test methods were selected that were appropriate for a non-supported plastic film. MIL-C-9959 test requirements were originally for a supported film, and only those test requirements that were appropriate for non-supported plastic film were used. In a few tests both test requirements of MIL-C-9959 and other test requirements were used for comparative purposes. The test results will be used for consideration when rewriting MIL-C-9959.

PHASE III - LABORATORY EVALUATION OF PROTOTYPE F-100 CONTAINERS

Twenty prototype flexible containers designed according to Global Drawing Code Identification No. 5403, Envelope, Engine Protective Outline and Mounting for F-100 Engine (Figure 9) were procured for field test and evaluation.

The First Article fit and function test was conducted at Pratt & Whitney Aircraft Corporation, Hartford, Connecticut. The assembly of the flexible container to the F-100 engine was performed easily, and the closure device was closed by finger pressure without auxillary tools. The performance of the container through the First Article fit and function test was satisfactory, and the test indicated that in field use the container should perform excellently. Dimensional changes for improved fit and desiccant pouch relocations were made.

Figure 10 shows the F-100 engine without the cover that was used during First Article fit and function test. Figure 11 shows the polyethylene foam sheets installed over the engine for physical protection from dropped items or hail stones. Figure 12 shows the top

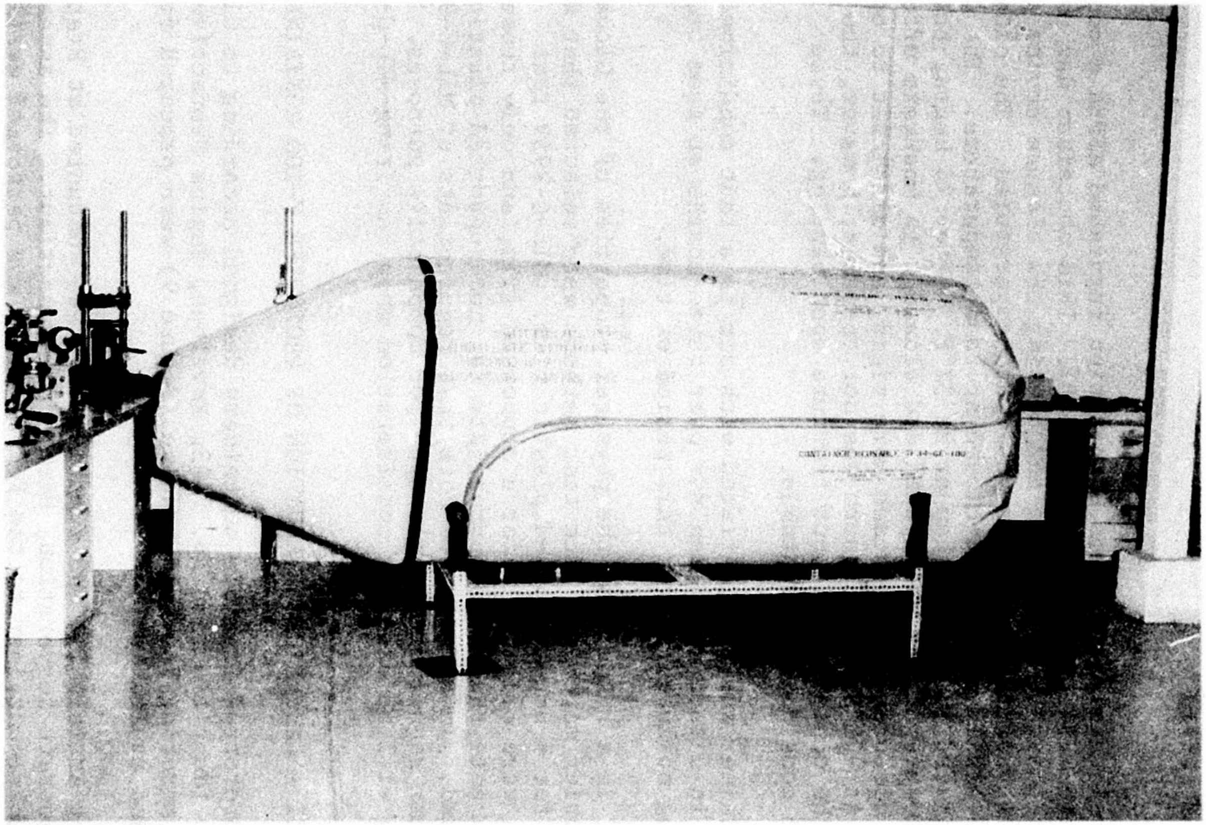


FIGURE 8. GLOBAL FLEXIBLE CONTAINER FOR THE TF34-GE-100

TABLE XI

SUMMARY OF THE PROPERTIES OF GLOBAL #4051*

PROPERTIES	METHODS OF TESTING	RESULTS ON GLOBAL #4050A
Flame Resistance	MIL-C-9959 - Time of flame not more than 5 seconds.	6 Seconds - Failed
Abrasion Resistance	MIL-C-9959 - FTMS-191; Method 2022 Penetration not greater than 50%	Excellent
	FTMS-406; Method 2022, H-18 Abrasive Wheels 500 gram load, 2000 cycles	Weight Loss - 0.07 grams Penetration not greater than 50% of thickness
Resistance to Aging	Air-oven aging, ASTM D573, 96 hrs at 180°F (Engineers Test Lab., Inc.)	Tensile Strength: Transverse - 6% Decrease Longitudinal - 3% Increase Elongation: Transverse - 12% Increase Longitudinal - 6% Increase
	Aged 72 hrs at 160°F/80% RH (AFPEA)	Tensile Strength: Transverse - 3% Decrease Longitudinal - 0.3% Increase Elongation: Transverse - 20% Increase Longitudinal - 7% Decrease
	Hydrolytic Aging, ASTM D3137 - 96 hrs at 185°F in saturated air (Engineers Test Lab., Inc.)	Tensile Strength: Transverse - 41% Decrease Longitudinal - 4% Decrease Elongation: Transverse - 2% Increase Longitudinal - 25% Increase
Resistance of Light	MIL-C-9959 - MIL-STD-810, Method 505 (Engineers Test Lab., Inc.)	No color change, cracking, crazing, deterioration or corrosion occurred.
Corrosiveness	MIL-C-9959	No corrosion

*MIL-C-9959 test requirements were used where applicable for non-supported film. Other tests were selected that were more appropriate for the non-supported Polyurethane/Saran laminate. The test facility is noted when significant.

TABLE XI (CONTINUED)

SUMMARY OF THE PROPERTIES OF GLOBAL #4051*

PROPERTIES	METHODS OF TESTING	RESULTS ON GLOBAL #4050A
WVTR - $GMS/100^{2''}/24$ hrs	MIL-C-9959 -	0.02 (50%/72°F) (Engineering Test Lab., Inc.)
After Room Temp Flexing and Before Exposure (Aging)	0.02 MAX (50%/73°F)	0.07 (95%/100°F) (AFPEA)
After Exposure (Aging)	0.03 MAX (50%/73°F)	0.06 (95%/100°F) (AFPEA)
After Low Temp Flexing	0.20 (MAX)	0.07 (95%/100°F) (AFPEA) 0.060 (95%/100°F) (AFPEA)
Cubic Foot (6 Sq Ft Area) Container	See Appendix for Method of Testing	0.07 (95%/100°F) (AFPEA) (With Closure) 0.009 (80%/80°F) (AFPEA) (No Closure) 0.003 (50%/72°F) (AFPEA) (No Closure)
Resistance to Blocking	MIL-C-9959 - No blocking - delamination	Excellent
Fluid Resistance	MIL-C-9959 - No leakage, swelling delamination, etc.	Excellent
Impact Puncture Resistance	MIL-C-9959 - Requires FTMS 101, Method 2025, Procedure A, Requirement - no puncture entirely through material when sample load is 60 pounds; 80 pounds.	 Satisfactory Satisfactory
Tensile Strength	MIL-C-9959 - Requires FTMS 191, Method 5100 not applicable to this type of material ASTM D-412-75 (AF Materials Lab)	As Received: Transverse - 2880 psi Elongation 90% Longitudinal - 3180 psi Elongation 100% Aged 72 hrs at 160°F/80% RH - Transverse - 2990 psi Elongation 65% Longitudinal - 3090 psi Elongation 120%

TABLE XI (CONTINUED)

SUMMARY OF THE PROPERTIES OF GLOBAL #4051*

PROPERTIES	METHODS OF TESTING	RESULTS ON GLOBAL #4050A
Tear Strength	MIL-C-9959 -FTMS 191, Method 5134 - 30 lbs min ASTM D1004	7.0 lbs 9.1 lbs
Weight Per Sq Yard	MIL-C-9959 - 3.1 pounds MAX	1.2 lbs
Bond Strength	ASTM D412 - Test specimens 1 inch strips with 1 inch overlap	As received 6200 psi
Volatility (Loss of Plasticizer)	ASTM D1203, Method A	0.28% Weight Loss

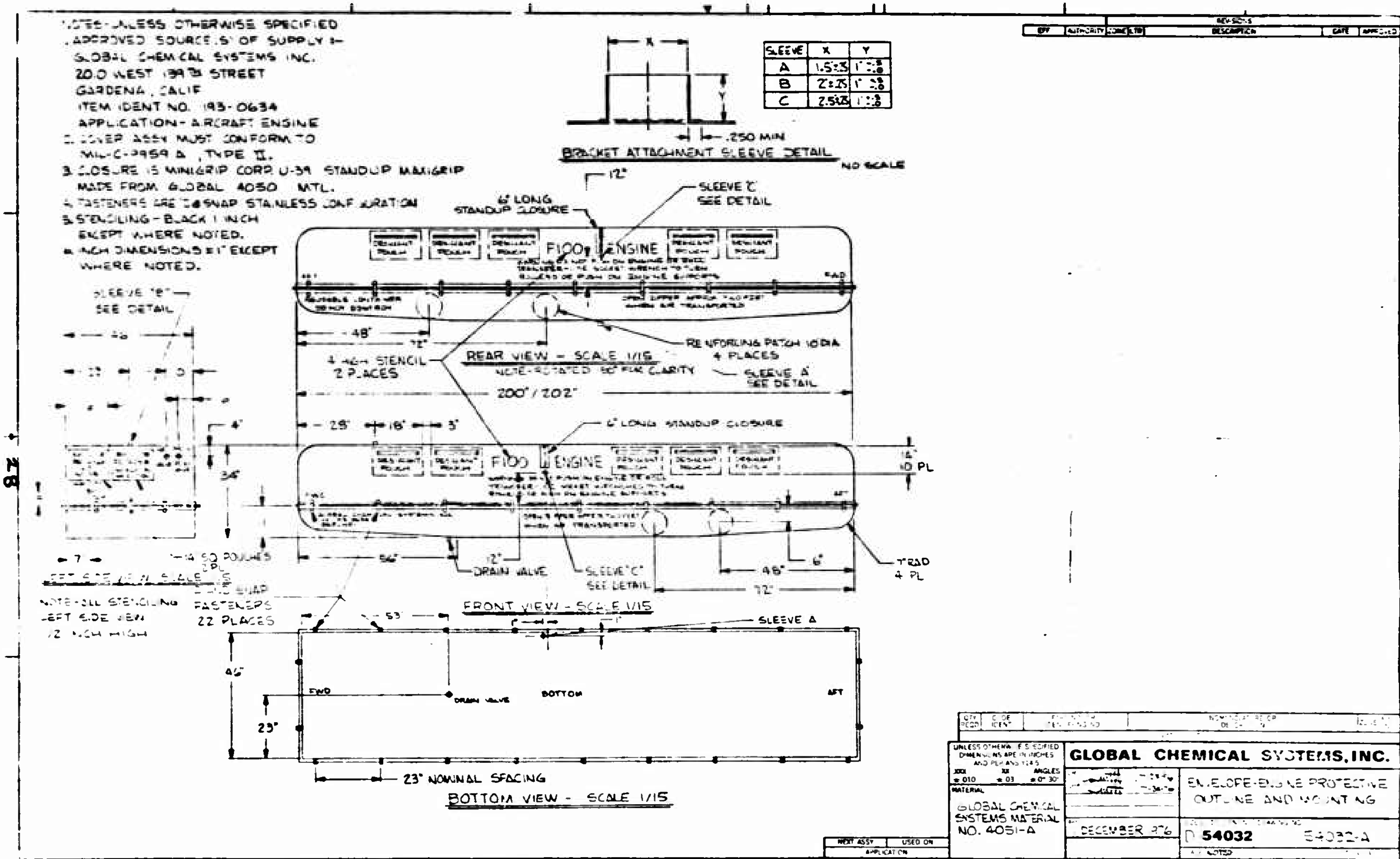


FIGURE 9. ENGINEERING DRAWING OF FLEXIBLE CONTAINER FOR F-100 ENGINE (F-15 Aircraft)

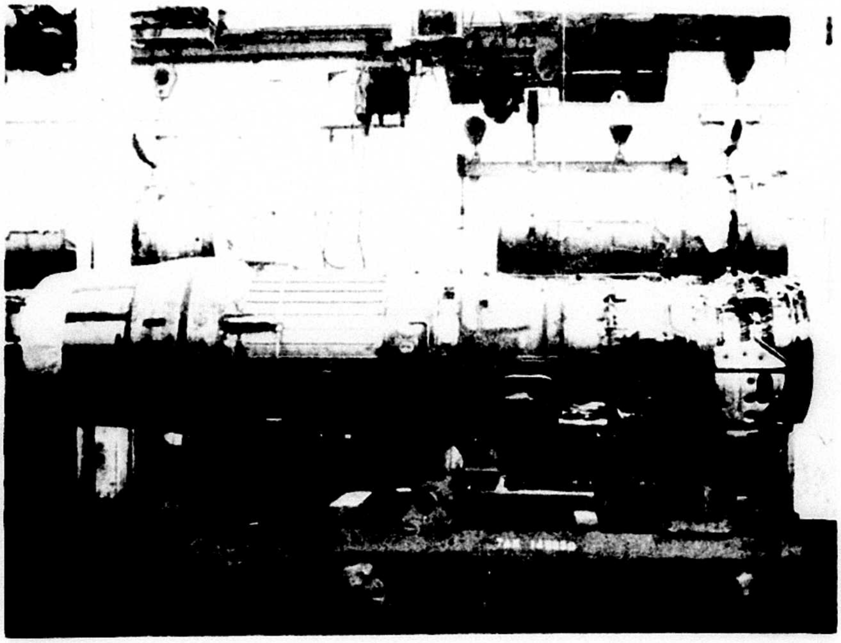


FIGURE 10. F-100 ENGINE MOUNTED ON HANDLING DOLLY

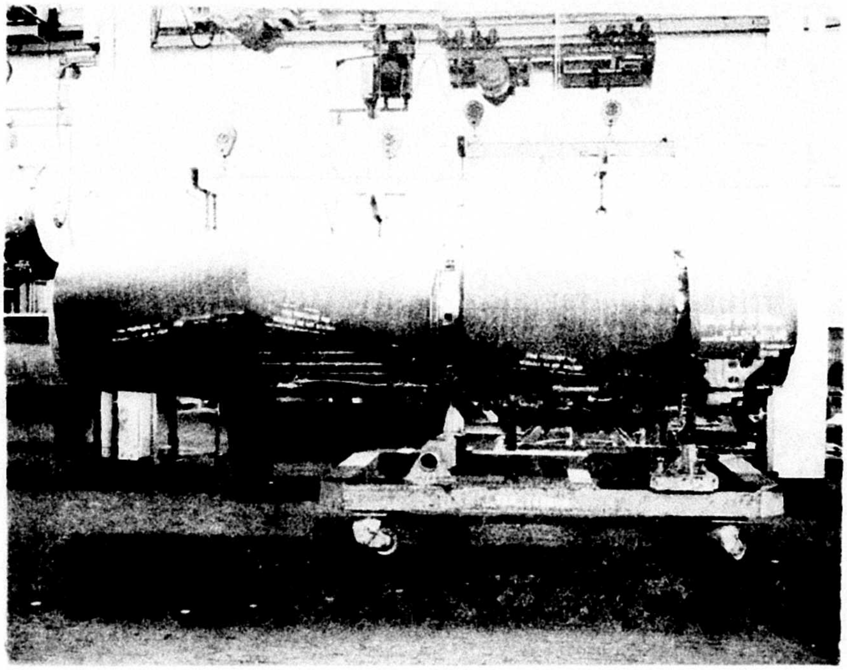


FIGURE 11. POLYETHYLENE FOAM SHEETS INSTALLED FOR PHYSICAL PROTECTION

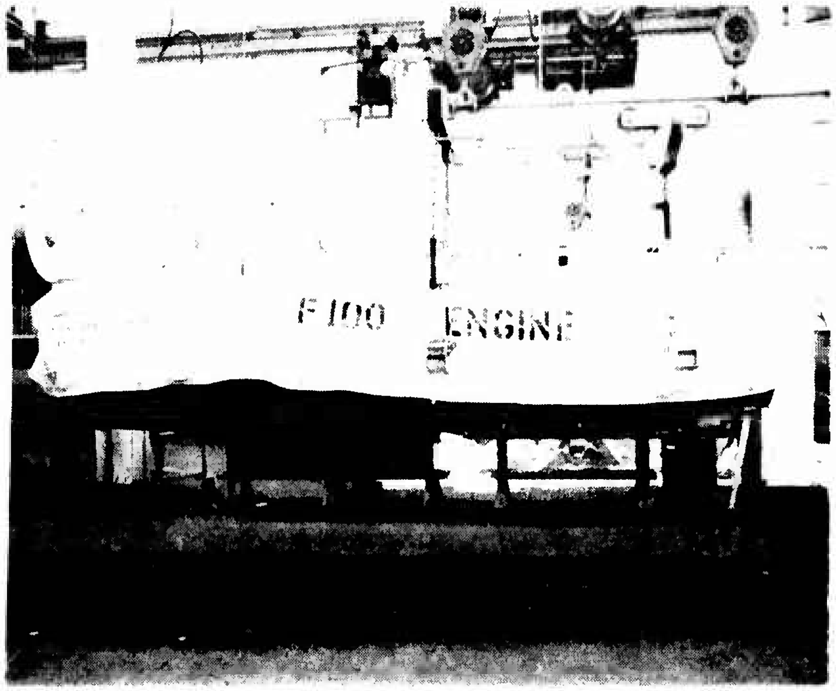


FIGURE 12. TOP HALF OF CONTAINER INSTALLED

half of the container installed. Figure 13 is the container completely installed and supported by the hoist. Figures 14 and 15 are a close-up of the closure device. Figure 16 shows the container/engine assembly mounted on 4-wheel trailer ready for transportation/storage.

The twenty flexible containers for the F-100 engine procured from Global Chemical Systems Incorporated were received in December 1976. It was noted on removal from the shipping container that the flexible containers were cracked completely through the thickness of the barrier material at the corner of the folds as shown in Figure 17. The containers averaged three to four cracks per container approximately 1/4" long. The containers were repaired using the patching kit that is supplied with the flexible container. The cause of the cracks was attributed to the method of packaging and the rough handling (shock and vibration) experienced at subzero temperatures during transportation by truck from Los Angeles, CA, to Wright-Patterson Air Force Base, Ohio.

To evaluate the effect of low temperature a folded container was drop tested from a 3 foot height at -20°F. The container cracked at folded corners of the container. A change in the packaging requirements will be made in MIL-C-9959, Container, Shipping and Storage as recommended (see Recommendation).

To evaluate the need for a pressure relief valve in flexible containers to provide possible relief of expanded air at 160°F and to provide for incoming air at lower temperature (to -65°F) a container with some free container surfaces (extra container material) was closed at 72°F. The container was conditioned for two hours at 160°F and examined; then conditioned at -65°F and examined. It was observed that sufficient free container surfaces were present indicating only a small expansion occurred at 165°F and only a small contraction occurred at -65°F.

Thermodynamically, the enclosed gas experienced constant pressure volumetrical change as a consequence of the temperature change. According to the ideal gas low $PV = nRT$ (P-pressure, V-volume, n-number of moles, R-ideal gas constant, T-absolute temperature) the percentage change in volume at 160°F was approximately 16.5%, and the gas contraction at -65°F was approximately 25.5%. Thus, a pressure relief valve is not required in a flexible container to accommodate volumetric change for temperature fluctuations from 160°F to -65°F.

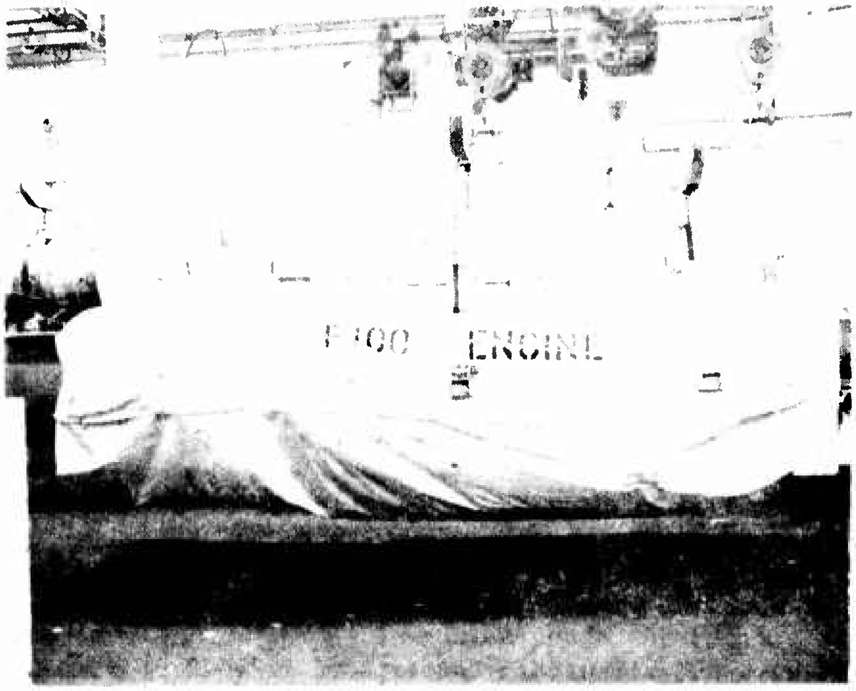


FIGURE 13. CONTAINER INSTALLED, ENGINE ASSEMBLY SUPPORTED BY HOIST

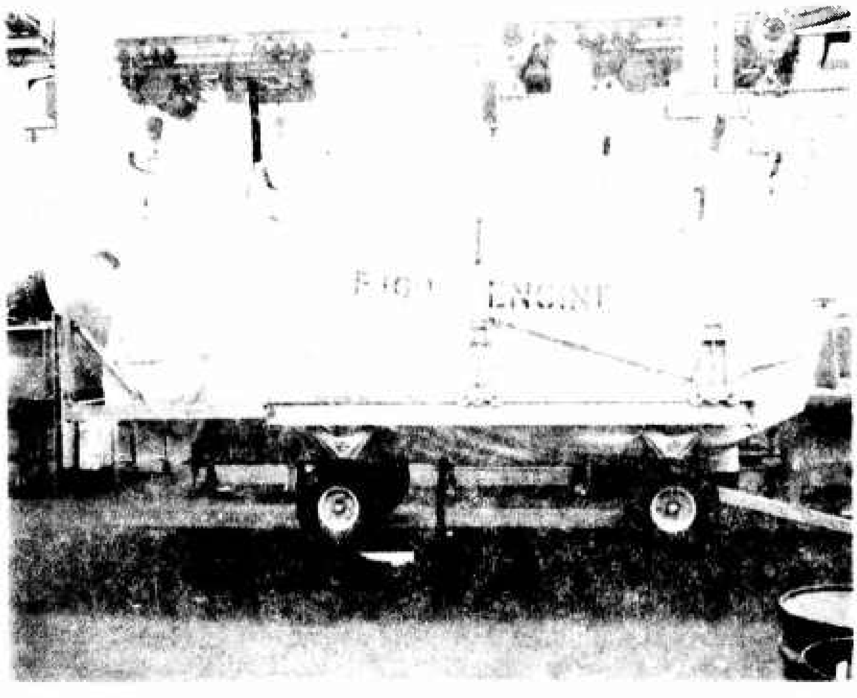


FIGURE 14. F-100 CONTAINER/ENGINE ASSEMBLY MOUNTED ON 4-WHEEL TRAILER

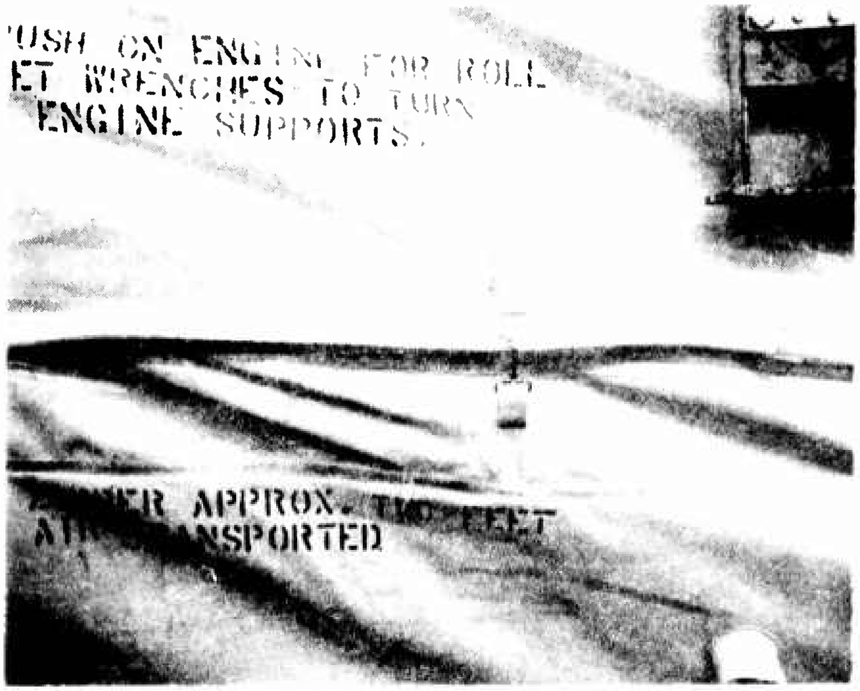


FIGURE 15. CLOSE-UP VIEW OF THE CLOSURE DEVICE WITH SNAP FASTENER

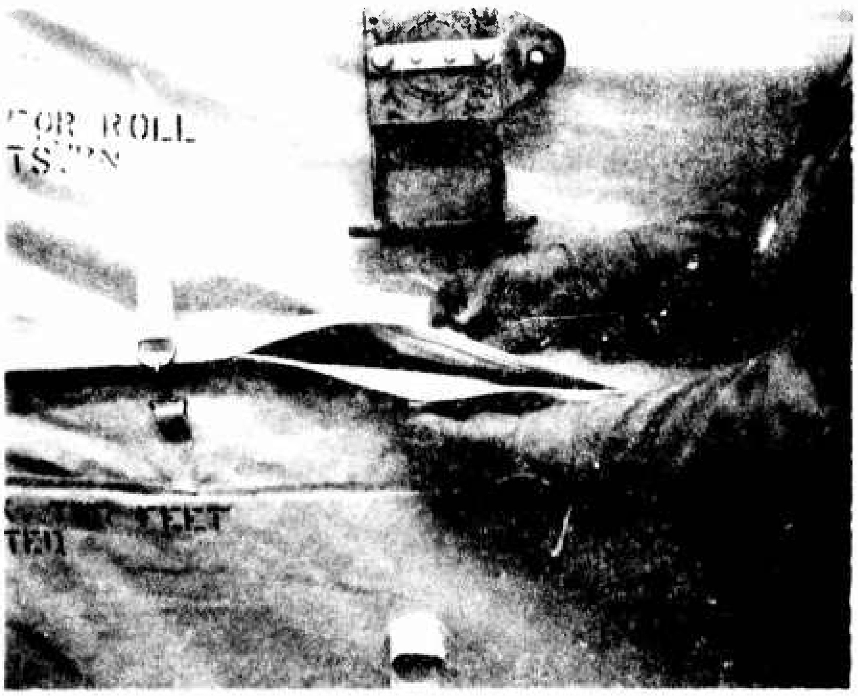


FIGURE 16. CLOSE-UP VIEW WITH CLOSURE DEVICE PARTIALLY OPEN

FIGURE 17. CRACKING AT THE CORNER OF THE FOLDS OF THE CONTAINER

To evaluate the opening of the closure device under internal air pressure a closed flexible container was subjected to an increase of air pressure until the closure device opened. The air pressure was measured with a water manometer. The closure opened at 6 to 8" of water. This demonstrates that if the closure is not opened before flight, as required, and decompression occurs, the container closure will open relieving the internal air pressure.

Twelve prototpye containers were shipped to Pratt & Whitney Aircraft Corporation, Hartford, Connecticut for field test and evaluation. The containers will be assembled to the F-100 engines and shipped to McDonnell-Douglas Aircraft Co., St. Louis, Missouri. The containers will be returned to Pratt & Whitney Aircraft Corporation for additional shipments. Two of the containers will be tested for one year protection period outdoors at Eglin AFB, Florida. The remainder of the containers will be used for laboratory evaluations.

CONCLUSIONS

The purpose of this project, to improve barrier materials for the construction of flexible aircraft engine containers, has been accomplished. Flexible engine containers manufactured from Global Chemical Systems Corporation barrier material number 4051 (polyurethane/Saran) and with Global's extruded polyurethane closure (PTPT Report No. 76-37) are strong, tough, light weight, resistant to petroleum products and synthetic lubricating fluids, resistant to sunlight, and abrasion. By relating the water vapor transmission rates to previous tested containers, the tests results indicate that the newly developed containers will provide a storage life of one year without redesiccation in a Florida environment.

With the newly developed closure device (Report No. PTPT 76-37) the containers are easily installed and removed from aircraft engines.

The First Article function and fit test was satisfactory, and indicated that in field use the container will perform excellently.

A pressure relief valve is not required in a flexible engine container to accommodate volumetric change for temperature conditions at 160°F and -65°F.

The closure device will open at a water manometer reading of 6 to 8". This demonstrates that if the closure is not opened before flight, as required, and decompression occurs, the container closure will open relieving the internal air pressure.

RECOMMENDATIONS

It is recommended that field tests and evaluations be conducted on the Global Chemical Systems Incorporated flexible containers manufactured with Global barrier material number 4051 and extruded polyurethane standup closure device. The field tests should include transportation and storage from Pratt & Whitney Aircraft Corporation, Hartford, Connecticut to McDonnell-Douglas Aircraft Co., St. Louis, Missouri and to other selected Air Force bases.

Requirements for flexible containers in MIL-C-9959 should be revised to specify the improved characteristics of the newly developed flexible container. The specification should also require that each flexible container shall be folded and packed in a exterior shipping container with all sharp edges and protrusions such as valves, and snap fasteners cushioned to prevent damage.

A program should be considered for extending the use of flexible containers for the environmental protection of other military items such as missiles and electronic equipment. The program should encompass the use of flexible containers for eliminating the need for a more expensive overpack such as water vaporproof metal or plastic containers, and the substitution of cheaper metal, plastic, or plastic foam containers which are not water vaporproof.

APPENDIX

WATER VAPOR TRANSMISSION RATE (WVTR) TEST
(Specified Test Period)
FOR FLEXIBLE CONTAINERS
(Variable Diffusion Rate)

1. SCOPE

1.1 This method was established for determining the water vapor transmission rate of flexible containers using variable (nonconstant) diffusion rates and specific protection periods. The method is applicable to selected barrier materials and closure devices fabricated to a one cubic foot volume and six square feet area cylindrical container. It provides a range of conditions of temperature and relative humidity to simulate atmospheric conditions which the flexible containers might encounter in service. With selected amounts of desiccant, the method can be used to determine specified protection periods or the protective storage life of the container. The diffusion rate is not held constant as in the absolute WVTR procedures (Federal Test Method Std No. 101B, Method 3030), but the diffusion rate is varied by the condition of the relative humidity varying from approximately 5 to 40% inside the container. This varying parameter more accurately represents field conditions, and should better evaluate storage life.

2. DEFINITION

2.1 Water vapor permeability (that is, water vapor transmission rate, WVTR) is defined for this method as the weight of water vapor transmitted through a given area of the test material in a given time, when the test material is maintained at a constant temperature and when one surface is exposed to very low but varying relative humidity and the other surface to a high constant relative humidity.

2.2 The Specific Protection Period of a container is defined as the minimum duration period (time) to reach 40% RH/72°F from a 5% RH/72°F environment inside the container when exposed to a selected test environment (% RH/°F). Selected amount of desiccant (MIL-D-3464) is used to extend the minimum duration period.

3. APPARATUS

3.1 The general apparatus shall consist of:

3.1.1 A test chamber or chambers capable of maintaining the environment at which the product is to be tested. The test chamber shall be provided with a suitable means for supporting each test assembly so as to afford free access of the conditioned air to the exterior surfaces of all specimens.

3.1.2 A test fixture built according to Figure 1. The cylindrical specimen is mounted on the test fixture by two clamping devices at the ends of the fixture.

3.1.3 Desiccant, MIL-D-3464.

3.1.4 An apparatus for determining the temperature and relative humidity of the environment inside the flexible container. (The apparatus used for this test was a Foxboro Dewcel, Foxboro, Co., and a Honeywell temperature and relative humidity measuring system, Honeywell Process Control Division.) The apparatus consists of temperature and dew cel/humidity sensing probes with necessary attachments to an indicator/recorder. Figure 2 shows the assembled test apparatus.

4. SPECIMENS

4.1 A specimen shall be a representative quantity of the flexible containers under test. A sufficient number of specimens shall be tested as necessary to adequately represent the material.

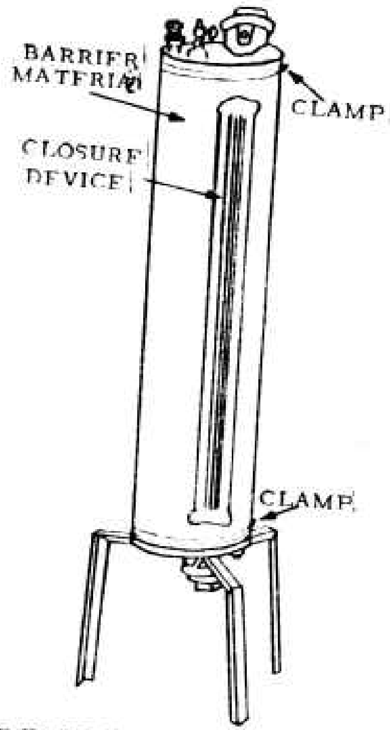
4.2 Each specimen shall consists of 8" + 1/4" diameter cylinder, 36" in length. A closure device representative of the subject flexible container shall be built into the specimen parallel to its length. The length of the closure device shall be 24 ± 1/4 inches. The closure device shall be attached to the specimen with the same manufacturing process that is used in making the flexible container.

5. CONDITIONING

5.1 Unless otherwise specified, the specimens need not be conditioned prior to assembly.

6. PROCEDURE

6.1 Unless otherwise specified, the test environment shall be one or more of the following combinations of relative humidity and temperature, depending on the end use of the flexible container:



1 CUBIC FOOT (6 SQUARE FEET AREA)
FLEXIBLE CONTAINER INSTALLED ON FIXTURE

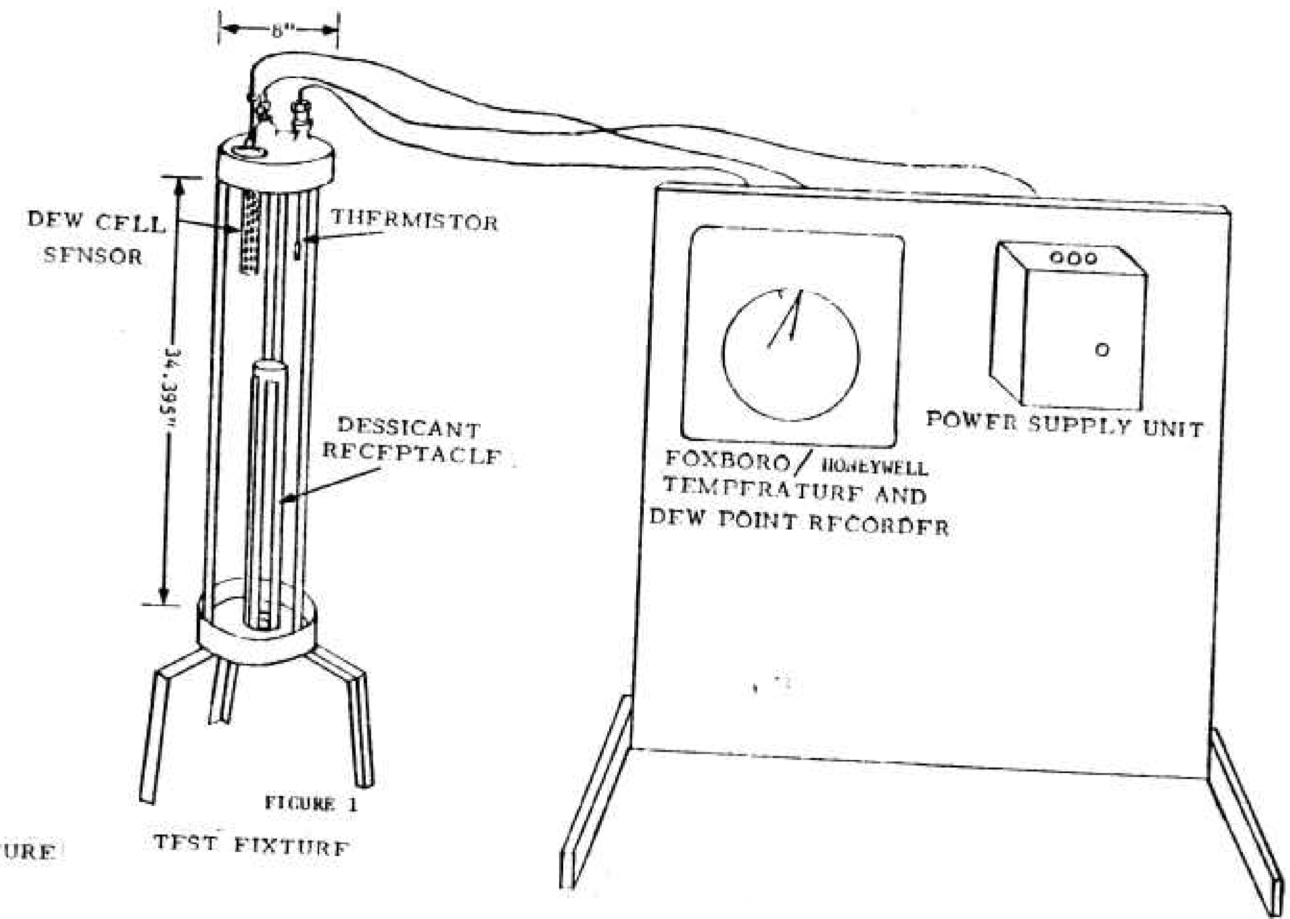


FIGURE 1

TEST FIXTURE

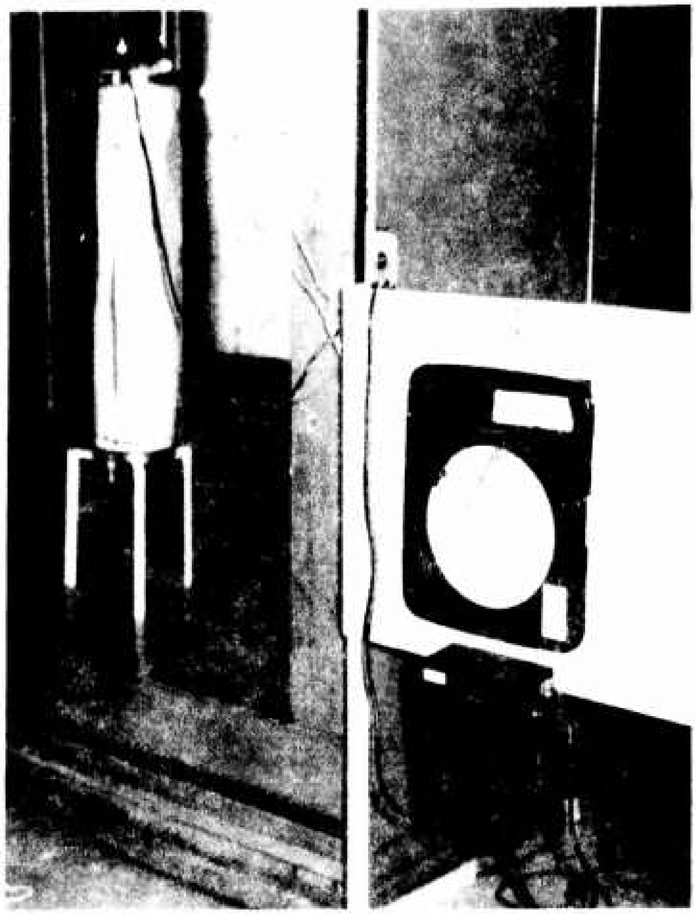


FIGURE 2. ASSEMBLED TEST APPARATUS

(1) 120° $\pm$ 2°F, 90 to 95 percent relative humidity.

(2) 100° $\pm$ 2°F, 90 to 95 percent relative humidity.

(3) 80° $\pm$ 2°F, 80 $\pm$ 2 percent relative humidity.

(4) 73° $\pm$ 2°F, 50 $\pm$ 2 percent relative humidity.

6.2 The specimen shall be installed on the test fixture making sure of no leakage. A halogen leak detector or the equivalent may be used to determine any leakage.

6.3 Start up apparatus to determine temperature and relative humidity according to manufactures instructions. Install desiccant into desiccant holders and condition the specimen at the above selected environment (6.1) for a minimum of 24 hours. The relative humidity inside the container should be allowed to stabilize at 5% or lower relative humidity.

6.4 Remove the desiccant.

6.5 When WVTR test is being conducted, place apparatus immediately into the selected relative humidity and temperature test environment chamber.

6.6 When Specific Protection Period test is being conducted, place selected amount of desiccant into desiccant holder of the test apparatus. Place assembled test apparatus into the selected relative humidity and temperature environmental chamber for the specified test period.

6.7 Remove test apparatus from test chamber when relative humidity of the environment inside the test container reaches 40% RH/72°F or the equivalent.

6.8 Record the times and dates at the start and the end of each of the tests.

7. REPORT

7.1 Following the completion of the test, a report shall be written which shall include:

7.1.1 A statement that the test was conducted in compliance with this procedure or a description of the deviation from it. Report all options selected as permitted in Paragraph 6.1, 6.5 and 6.6.

7.1.2 A description of the material tested including the chemical composition, description of the closure, and the average, minimum, and maximum thickness of the sheet on which the test was performed. Refer to any preceding tests or treatment of the specimens.

7.1.3 The temperature and relative humidity of the test environment and the temperature and relative humidity inside the container at the start and at the end of the test period shall be recorded.

7.1.4 The average water vapor transmission rate expressed as grams per 100 square inches per 24 hours shall be calculated as follows:

General Calculation:

$$\text{WVTR} = \frac{\text{Grams per Vol at final minus Grams per Vol at start (Vol) (100)}}{\text{Area}}$$

Specific Calculation:

$$\text{WVTR} = \frac{[(\text{A final})\ (\text{B final}) - (\text{A start})\ (\text{B start})]\ [0.028317\text{m}^3]\ (100)}{864}$$

$$\frac{[A_f B_f - AiBi]\ [.028317]24}{8.64\ T} \quad \text{(grams per 100 sq in per 24 hrs)}$$

A = Grams of Water per cubic meter at Saturation (Langes Hdbk of Chemistry)

B = Decimal Equivalent of Percent of Relative Humidity

T = Test Period - Hours

One Cubic Foot = 0.028317 Cubic Meters

Six Square Feet = 864 square inches

7.1.5 The specific Protection Period test result shall be expressed as Passed or Failed in the selected minimum duration period.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER PTPT Report No. 76-21	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9 Interim rept.
4. TITLE (and Subtitle) 6 INTERIM REPORT - THE DEVELOPMENT OF BARRIER MATERIALS FOR FLEXIBLE AIRCRAFT ENGINE CONTAINERS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER 14 PTPT Report No. 76-21
7. AUTHOR(s) 10 Mr. Paul/Robbins		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFALD/PTPT Wright-Patterson AFB, OH 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AFPEA Project No. 75-P7-30
11. CONTROLLING OFFICE NAME AND ADDRESS AFALD/PTPT Wright-Patterson AFB, OH 45433		12. REPORT DATE 11 May 1977
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 51p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Container, Flexible
Barrier Materials
Plastic, Films
Water Vaporproof Transmission Rates
F-100 Engine Container
Polyurethane Films
Saran Films
Polyurethane/Saran Laminates
Aircraft Engine Container
Protection, Envrionmental
Closure Device, Plastic

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The development of improved barrier materials for the construction of flexible aircraft engine containers in conjunction with a newly developed closure device (DSPS Report No. 76-17) has been completed. An extensive investigation was conducted on the properties of flexible plastic laminates and composites for barrier materials. Flexible containers fabricated from the selected barrier materials are stronger, tougher, and offer greater resistance to environmental elements than previous materials, providing over one year protection without

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redesiccation. They are easily installed and removed from the aircraft engine. Field tests are recommended before approval for production quantities.